SWAN LAKE PUMPED STORAGE

PROJECT STATUS, SYSTEM BENEFITS AND BARRIERS

California Public Utilities Commission

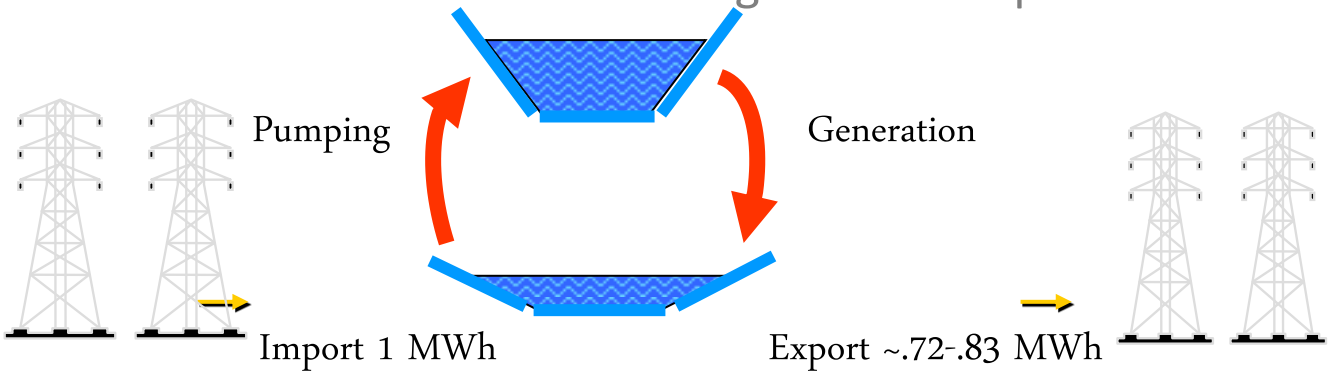
Technical Workshop

San Francisco, CA

January 16, 2014

AGENDA – PUMPED STORAGE IN CALIFORNIA

- EDF Renewable Energy and EDF Group capabilities
- Swan Lake Project details
- California has substantial needs for storage resources. Pumped Storage provides benefits including grid scale storage + short and longer duration services that span the spectrum of ancillary services and characteristics needed for the grid
- Challenges to Pumped Storage: among other challenges, future projects require meaningful regulatory action from the CPUC and other agencies if its potential is to be realized
- Recommendations

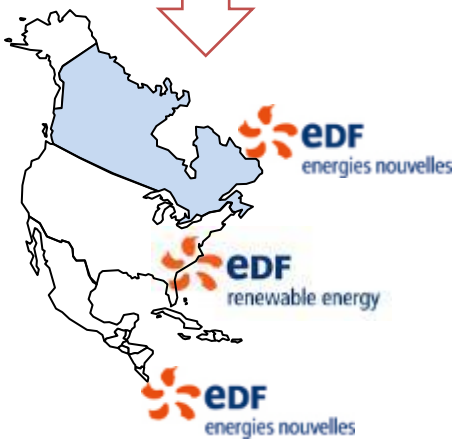


EDF renewable energy

EDF RENEWABLE ENERGY (FORMERLY ENXCO)

100% Owner of EDF EN Group

100% Owner of EDF Renewable Energy, EDF EN Canada Inc. and EDF EN Mexico



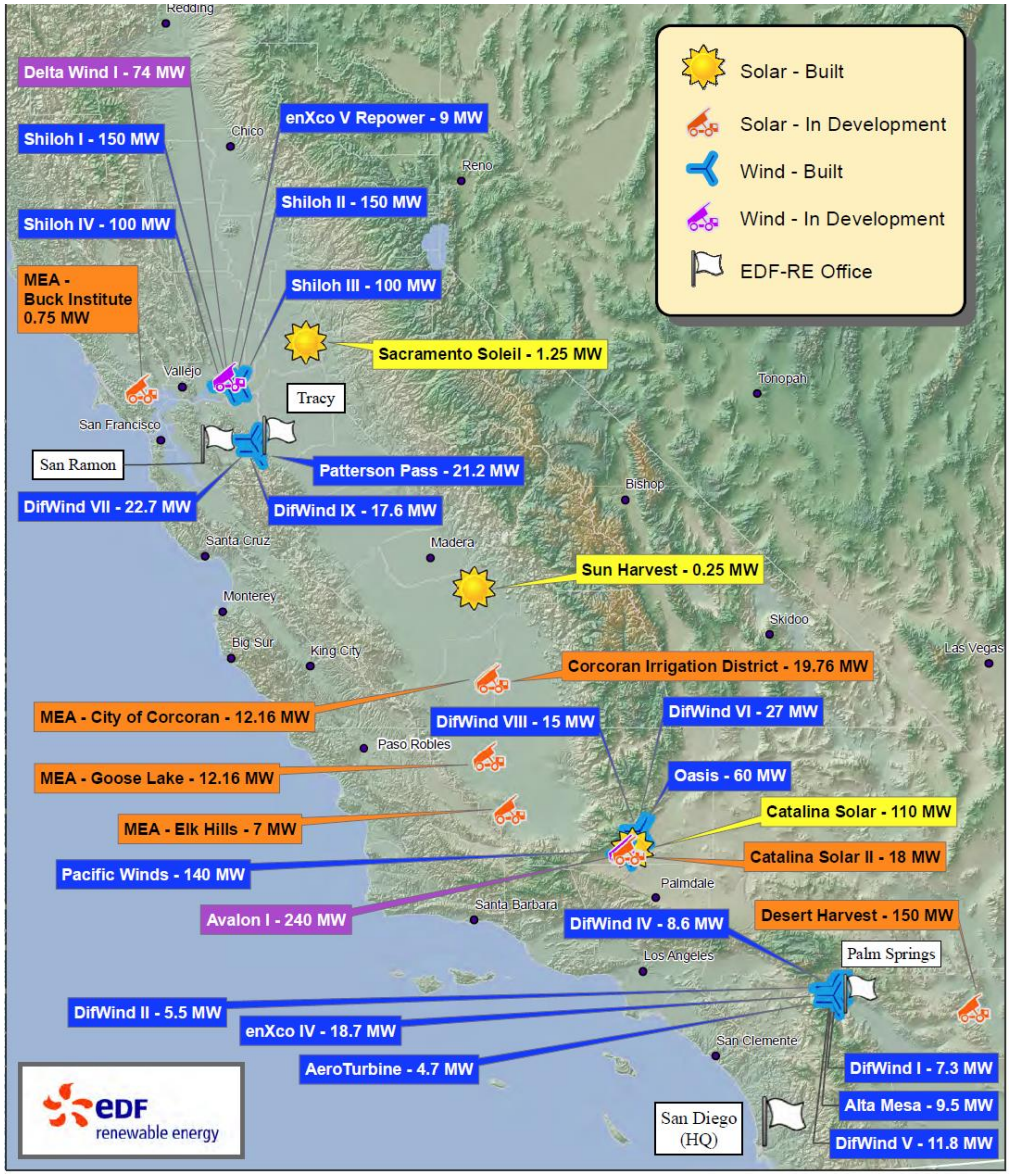
EDF Group (2012)

Employees (World)	160,000
Installed Capacity	140 GW
Installed Renewables	3.3 GW
Sales	€72.7bn ($US98.8bn)
EBITDA	€16.1bn ($US21.9bn)
S&P	A+
Worldwide Customers	39.3MM
Headquarters	Paris, France

EDF Renewable Energy (2012)

Employees (N America)	873
Installed Capacity	2382 MW
Commissioned in 2012	1057 MW
O&M Portfolio	6347 Turbines
	2.3MM Solar Panels
Years in Business	25
Headquarters	San Diego, CA

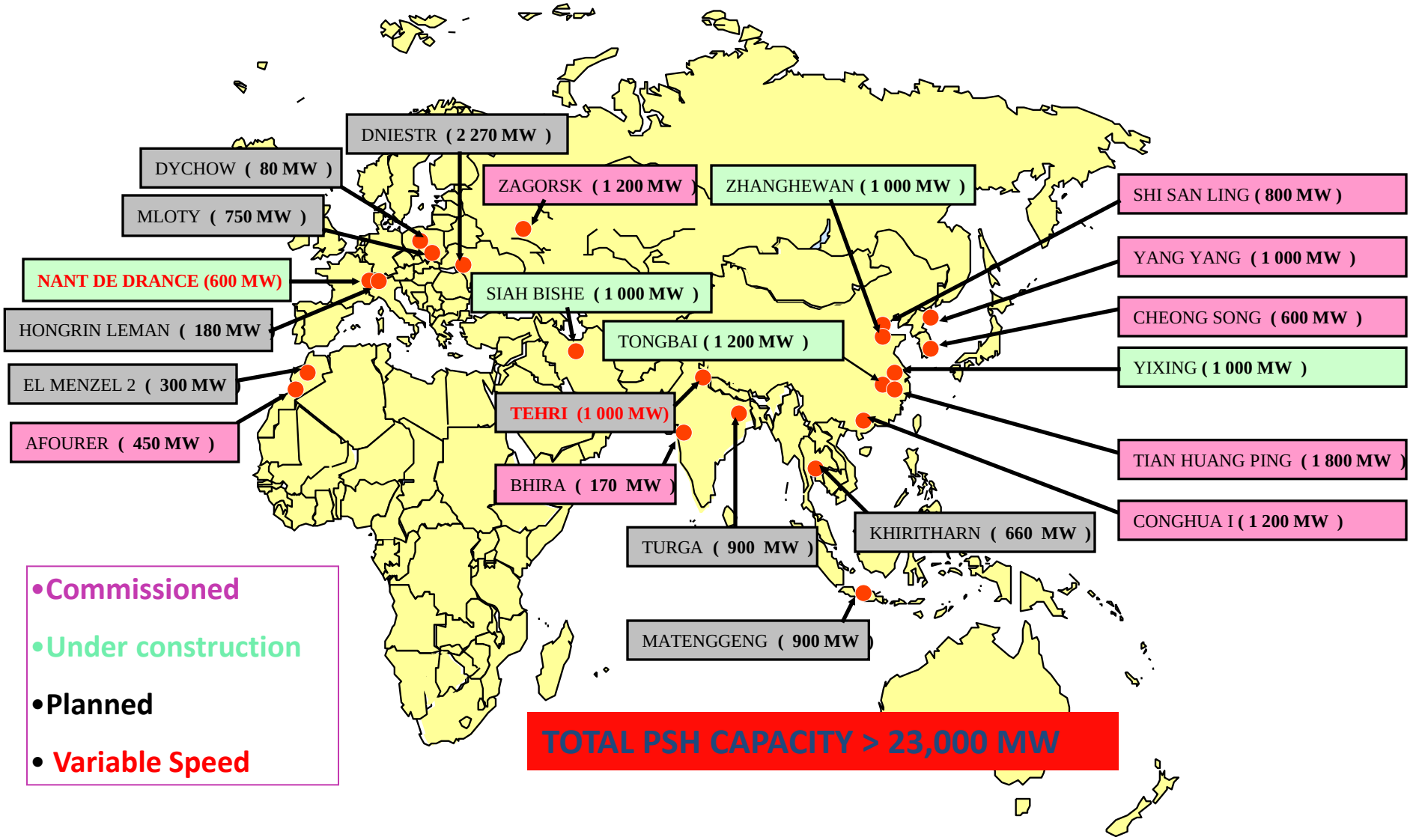
EDF-RE AND CALIFORNIA



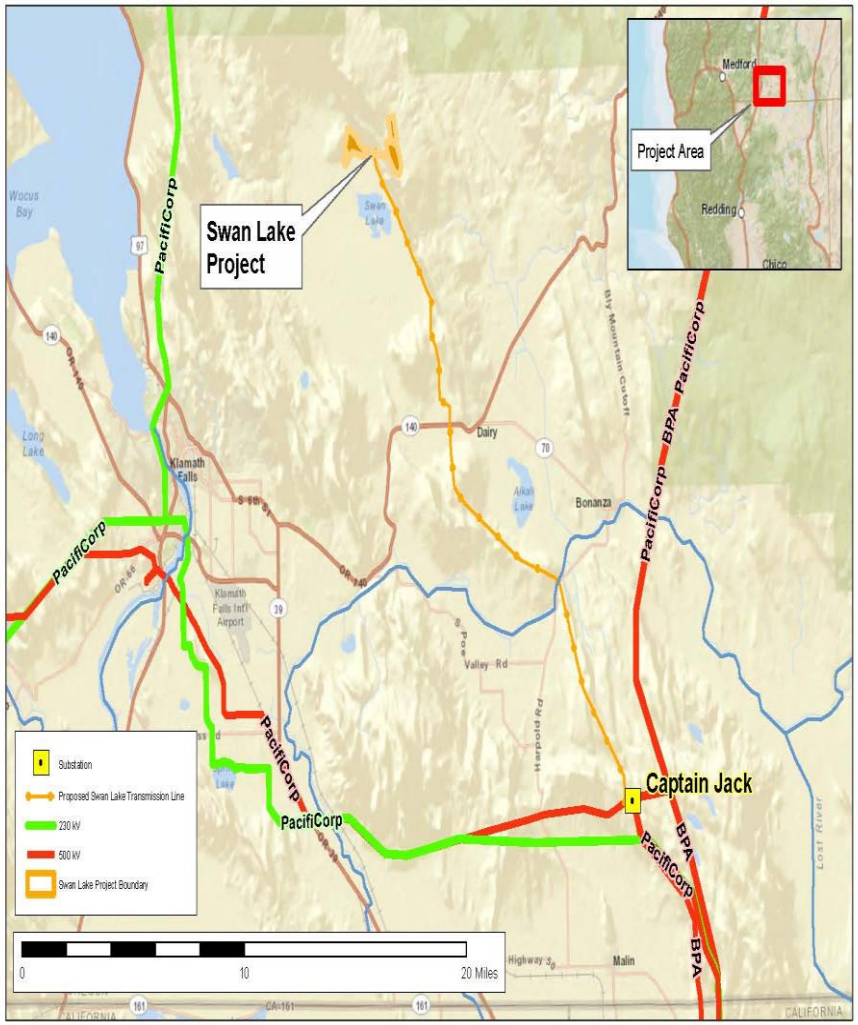
- North American HQ is San Diego, with offices in San Ramon, Tracy and Palm Springs
- "Born and raised" in California
- We have California projects in various stages of development
- We have sold projects to, or entered into PPAs with, all segments of the utility community in California (IOUs, munis)

EDF'S PUMPED STORAGE HYDRO GLOBAL PRESENCE

Global Overview of EDF Pumped Storage Hydro Projects



SWAN LAKE PROJECT OVERVIEW



Location:

- Approximately 11 miles NE of Klamath Falls, Oregon
- Project Area: 837 Acres
- Private and BLM Property
- Water Availability:
  - Leased groundwater rights, preliminary OWRD approval
- Transmission Access
  - South of Malin; near COB; PacifiCorp and CAISO

- **Total Capacity: 600MW - System Need Dependent**
- Project Head: 1265 feet
- Hybrid Penstock Design
  - Upper half of penstock above ground
  - Lower half of penstock below grade
  - EDF-CIH approved preliminary design.
- Below-Grade Power House and Substation
- Closed-Loop System
  - New upper and lower reservoirs
  - No impact to existing water ways
  - Initial fill and evaporation from existing ground water wells
  - Water rights have been secured

EDF renewable energy

STORAGE TECHNOLOGY AND TIME SCALE COMPARISONS

Seconds to 15 Min	1 Hour to 4 Hours	Several Days
▪ Super capacitors ▪ Flywheels ▪ Batteries ▪ **Pumped storage (includes inertia, primary and secondary frequency control)**	▪ Batteries ▪ Compressed air energy storage (CAES) ▪ **Pumped-storage**	▪ **Pumped-storage**

15 Min to 1Hour	4 Hours to 1 Day
▪ Batteries ▪ Compressed air energy storage ▪ **Pumped storage**	▪ CAES ▪ **Pumped-storage**

Pumped Storage provides grid scale storage + short and longer duration Ancillary Services; spans the spectrum of capacity services

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STORAGE & ANCILLARY SERVICES

Benefits

- Flexible capacity for Renewables Integration:
  - Helps fulfill current and future RPS targets
  - Hedges against natural gas price spikes and shortages and overreliance on gas, helps avoid need for gas storage
  - Help in the Reduction of Greenhouse Emissions, and reduces vulnerability of energy supply infrastructure and demand due to effects of climate change
  - Supports job growth
  - Pumped Storage addresses all timescales of the US ancillary service market
- PSH Provides Superior Intra-Hour Flexibility:
  - Superior AGC response for regulation
  - Superior ramping capability for early load following period (as well as for longer duration ramping needs)
- Optimize Off-Peak Generation; benefits as a load:
  - Shave off-peak gen/ decrease wind curtailment; Can serve as load when needed

A complementary option to help stabilize the grid and provide greater operating flexibility, as part of comprehensive package

STORAGE & ANCILLARY SERVICES

Challenges

- Market Deficiencies
  - The duration of the limited existing Ancillary market insufficient for long term private sector investment
  - Providing revenue certainty to bulk storage projects sufficient to attract investors
  - Struggle over Generation or Transmission/Existing Market Rules and Impact on Energy Storage Value
- Environmental Issues for Pumped Storage Siting:
  - The concept of “closed-loop” pumped storage is now the standard approach because it presents minimal to no impact to existing rivers
- Fluctuating power from available wind energy and other renewable forms of production have to be integrated.
  - Greater net load grid impacts
  - Minimum load challenges
  - Difficult to Predict
  - Might not be there when you need it…..
  - Might have too much of it when you don’t…

PUMPED STORAGE BENEFITS AND VALUES

- Regulation Reserve; (value contributions include inertial response, governor response or primary frequency control, and regulation reserve or secondary frequency control)
- Flexibility Reserve/ load following
- Contingency Spinning, non-spinning and replacement reserves
- Energy arbitrage/ load leveling
- Integration of variable energy resources (VERs)
- Capacity
- Portfolio effects/ reduced cycling of thermal units/ reduced fuel and O&M expense
- Reduced transmission congestion
- Reduced environmental emissions
- Transmission deferral
- Voltage support
- Black start capability

EDF RE DETAIL PUMPED STORAGE MODELING

- Our Swan Lake project modeling is building on the approach used by Argonne National Laboratory, et al.; we are identifying intra-hour values, portfolio values, avoiding renewable curtailment, other values so that what Pumped Storage contributes to the system in all material time frames is made clear.

- Modeling the Western Interconnect and CAISO without and then with Swan Lake, using Plexos, a power system operation simulation software package by Energy Exemplar as described by ANL today.

- Using 2022 as the future year for analysis, based primarily on the recent vintage 2022 WECC TEPPC data base, with careful assumption vetting.

- Measuring Day Ahead (DA) and Hour Ahead (HA) measurement for all hours; Real Time (RT) 5 minute step measured for 4 typical weeks for 4 seasons, but evaluating doing for 12 typical weeks for 12 months.

- Diversion from Argonne National Lab study approach:

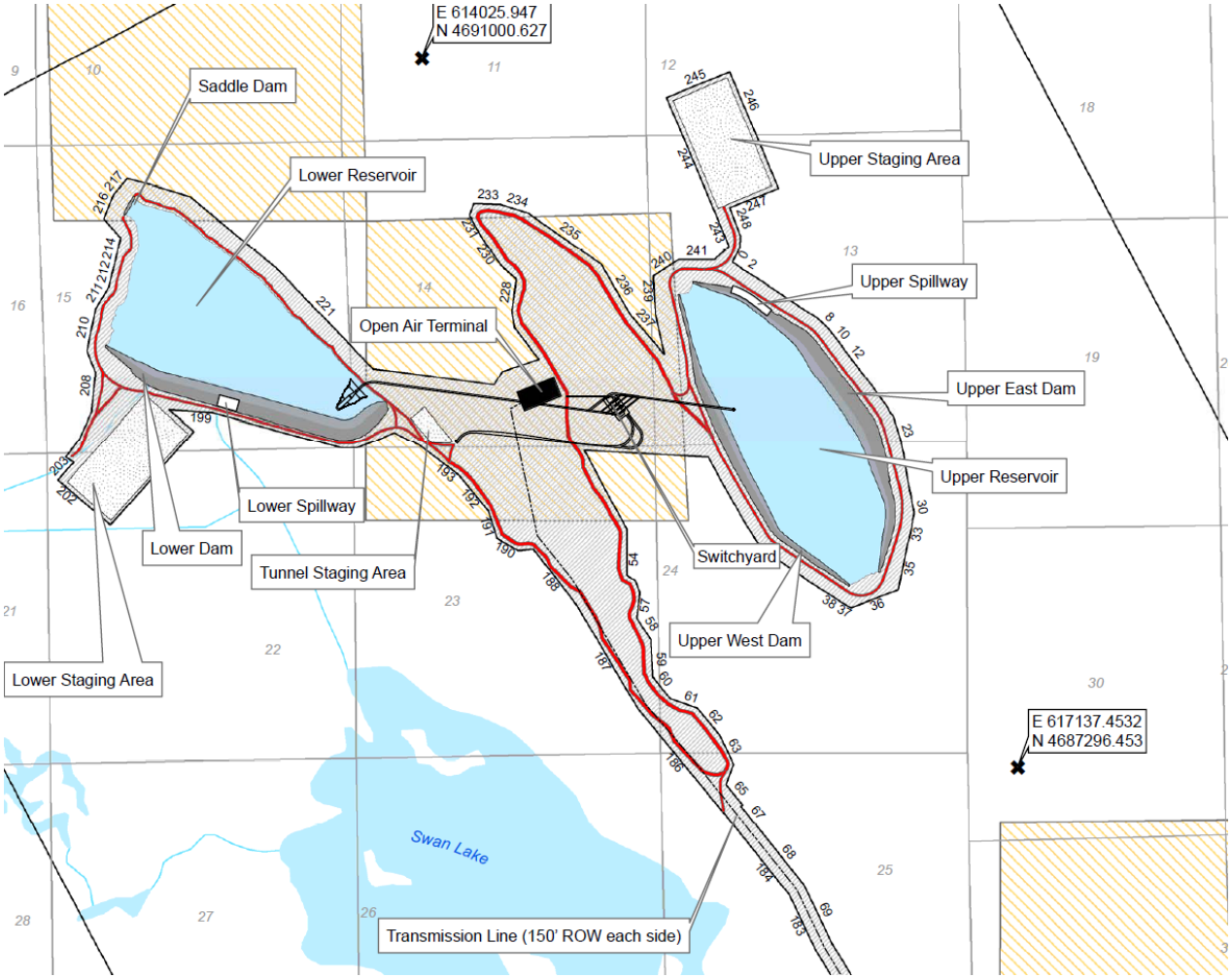
  - Only base RE scenario studied (using all 2022 legal requirements in WI states); no high RE scenario
  - All existing fixed speed Pumped Storage in base case; Swan Lake only variable speed Pumped Storage added
  - SL direct interconnect into CAISO
  - Nodal representation of transmission system in CA, OR,W, NV; rest of WI zonal
  - Thermal start up costs will include not only fuel but also related incremental O&M (from Aptex)
  - Assessing avoided GHG emissions value post-modeling
  - Updating of TEPPC on retirements, topology, hydro system operation
  - Additional case for head to head comparison with CCCT (600 MW @ California-Oregon Border)
  - Adding high gas price case and low/high water year case

UTILITY STORAGE RECOMMENDATIONS

- Identify and measure value streams and compensate more of them.
- Include intra-hour values and portfolio effects in value determination.
  - Focus on critical time parameters for effective integration of renewables: especially intra-hour; morning dec ramp; evening inc ramp.
- Provide recognition of fast and accurate frequency regulation performance, as encouraged by FERC in order No 784, and corresponding premium incentive
  - Prorata with performance exceeding thermal fleet average.
- Provide premium incentive for premium ramping capability
  - Compare PSH resource ramp speed with fleet average of resources committed HA.
- Provide long term contract term availability for Pumped Storage as a preferred resource; 30 year term best.
- Reward premium Pumped Storage performance over thermal fleet in time frames of particular significance to the system; i.e., intra-hour, morning dec ramp and early evening inc ramp.

APPENDIX

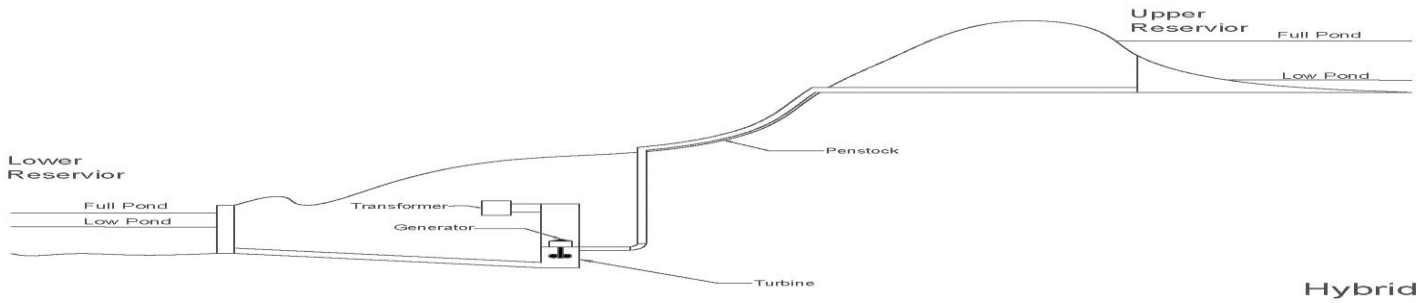
SWAN LAKE SITE PLAN



HYDRAULIC CONVEYANCE & POWER HOUSE

Design

- Hybrid water conveyance, mainly for geological reasons
  - **Penstocks at the Upper end**
  - **Underground Tunnel at the lower end to a subsurface Powerhouse**



- Moderate visual impact
- Limit the up-front costs
- Remain within the boundaries determined in the Preliminary FERC Permit
- Locate the power plant “far” from the active fault passing under the left extremity of the lower dam that is assumed to be active
- Remain in the expected “good rock” ,i.e. Pliocene basalt of Bear Wallows and avoid as much as possible tertiary sediments (Ts)

GEOPHYSICAL INVESTIGATION

- Swan Lake North will analyze and evaluate field data, test results and reporting to determine the feasibility of the plant site with respect to the suitability of geophysical characteristics

- Field Work for Phase 1 - Lower Reservoir - Initial Studies Complete
  - 6 Standard Penetration Tests, ranging in depths from 35 to 65 feet
  - 1 Core Borehole, 120 ft deep
  - 3 Seismic Refraction Profiles , ranging in lengths from 4,211 to 6,246 feet

  - Objective:
    - Suitability of Soil – A bed of silt estimated to be up to 30 feet deep in places covers the lower reservoir floor. For some soils, potential for liquefaction to occur in the event of an earthquake. Determine depth of soils with liquifaction concern and potential for liquefaction. Initial results positive; limited to 1.5 meter shallow layer.
    - Evaluation of the impact of the lower escarpment fault on the primary dam and escarpment interface; pending.

- Field Work for Phase 2 - Upper Reservoir, Conveyance, Shafts, Powerhouse - Pending
  - 5 Core Boreholes, ranging in depths from 60 to 660 feet
  - 2 Seismic Refraction Profiles at 1,981 and 6,246 feet in length

- Suitable geophysical characteristics to support the Lower Reservoir will be a prerequisite for the option to commence with Phase 2.

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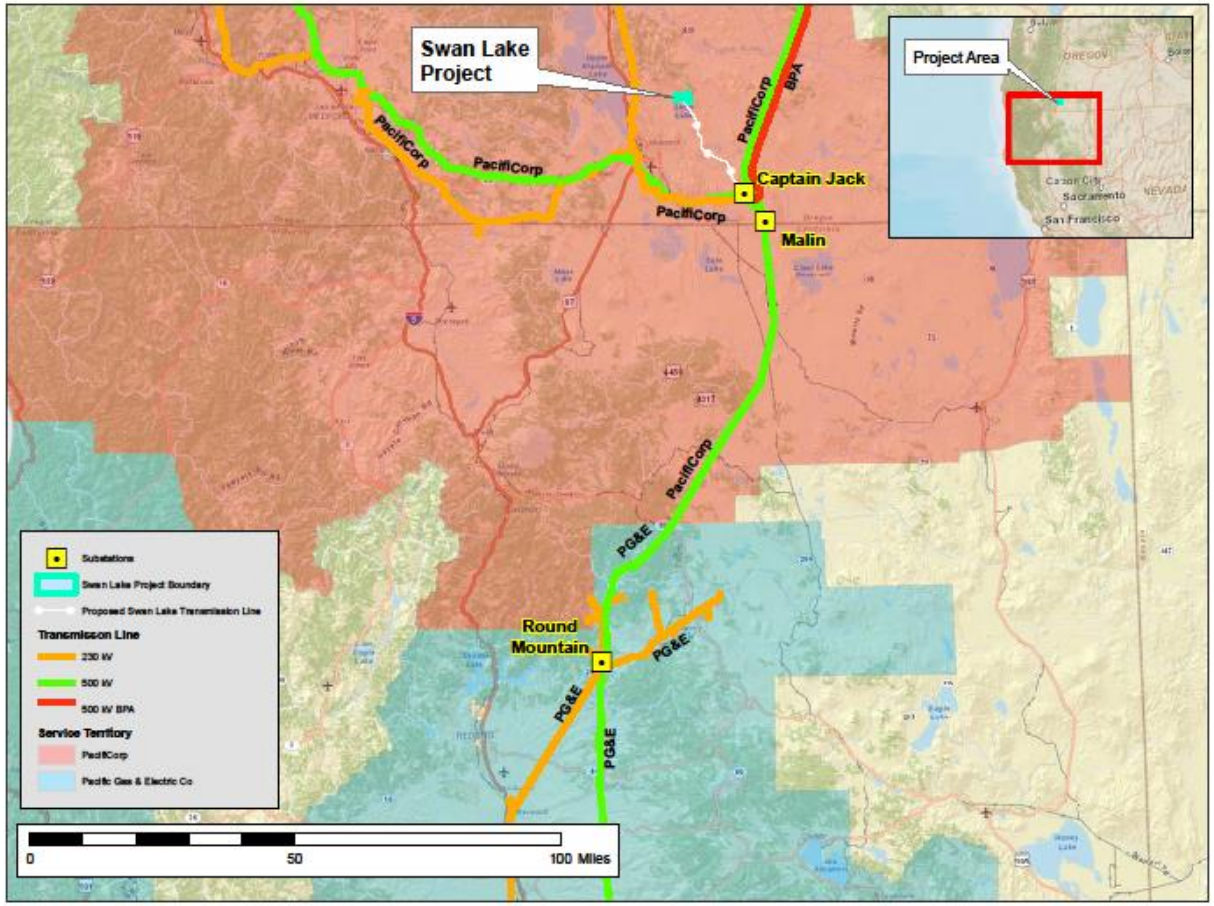
SWAN LAKE POTENTIAL INTERCONNECTION



- PacifiCorp Large Generation Interconnection Request submitted in August, 2013
- Planning on gentie to vicinity of Malin; route included in FERC draft license application.
- Study interconnection on PacifiCorp-owned line segment south of Malin; subject to Facilities sharing agreement with PG&E/CAISO
- Will include preferred substation location in final FERC application.

MODEL FEATURES- BIG PICTURE

- Measures Benefits and Costs DA, HA, RT; adds intra-hour measurement down to 5 minute timing, captures intra-hour value.
- Co-Optimizes Energy Arbitrage and Ancillary Services; evaluates Ops reserves (Reg and Flex up and down), Contingency Reserves (spin and non-spin), integration of Variable Energy Resources, capacity value, portfolio effects (e.g., reduced cycling and starts), to produce production cost reductions or AS revenue.
- Captures almost all Ancillary Service benefits and portfolio effects (a couple of AS like voltage support and black start are not captured in the model but will be evaluated outside the model.)
- Identifies congestion reduction, transmission deferrals, emissions reductions of SOx, NOx, CO2, other emissions, although not all are currently monetizable.
- The goal is to identify and accurately quantify as many value streams as possible, and to identify which can be described as social benefits and targeted for potential policy change to support monetization.

STORAGE WHITE PAPER

- The purpose of the Storage White Paper is to provide a concise source for information on the value of energy storage technologies and techniques analysts use to quantify that value.
- It is intended to accompany the Swan Lake modeling study and to provide a summary of pertinent information and a guide to recent reports about storage, as a tool for regulators and staff, intervening stakeholders and others who may participate in regulatory proceedings in CA and/or the NW states, to push forward a relatively high level discussion of storage attributes, benefits, costs, challenges, and policy considerations, to improve recognition and support of storage in the market.
- The White Paper effort is being headed by Ken Dragoon of Ecofys, an international sustainable energy consulting firm, with a very extensive Advisory Panel including representatives of regional investor owned and municipal utilities, PUC staffs, advocacy groups, Federal Laboratories, universities, power councils and similar entities. (see appendix)
- The White Paper is in draft process now, Goal is final draft by January 16, final review and availability to follow up on January 16 CPUC workshop.

WHITE PAPER ADVISORY PANEL

❖ Advisory Panel Members:

Eddie Abadi – Bonneville Power Administration
Dick Adams – Pacific Northwest Utilities Conference Committee
Ellis Arzu - EDF Renewable Energy
Jamie Austin - Pacificorp
Mark Avery – Salt River Project
Frank Bergh – Nordex
Damian Buie - EDF Renewable Energy
Ronald Bushner - Hawaii Electric Company
Yong Cai – Sacramento Municipal Utility District
Gillian Charles – Northwest Power and Conservation Council
David Clement – Seattle City Light
Stephen Enyeart - Bonneville Power Administration
Erin Erben – Eugene Water & Electric Board
John Fazio - Northwest Power and Conservation Council
Christopher Fecke-Stoudt – K.R. Saline & Associates
Hassan Ghoujehbaklou – San Diego Gas & Electric
Michael Goggin – American Wind Energy Association
Adam Green – Solar Reserve
Tao Guo – Energy Exemplar
Douglas A. Halamay – Oregon State University
Udi Helman – BrightSource Energy
Alan Hickenbottom – Christianson Electric
Matthew Hunsaker – Western Electricity Coordinating Council
Steve Johnson – Washington Utilities and Transportation Commission
Rebecca Johnson – Western Interstate Energy Board
Brendan Kirby - Private Consultant

Ben Kujala - Northwest Power and Conservation Council
Larry La Bolle – Avista Corporation
Jimmy Lindsay – Renewable Northwest Project
Clyde Loutan – California ISO
Pavel Mardilovich – NRG Independence
Michael Milligan – National Renewable Energy Laboratory
Dora Nakafuji – Hawaii Electric Company
Rebecca O'Neil – Oregon Department of Energy
John Ollis – Portland General Electric
Rich Pagoaga, Jr. – Idaho Power Company
Leah Parks Schoinas – ElectricityPolicy.com
Glenn Patterson – Christianson Electric
Dana Peck - EDF Renewable Energy
Robert Petty - Bonneville Power Administration
Will Price - Eugene Water & Electric Board
Greg Probst - EDF Renewable Energy
Ron S. Sporseen – PK Energy Solutions
Ishwar Saini – Macquarie Group Limited
Steve Simmons - Northwest Power and Conservation Council
Andrew Speer - Bonneville Power Administration
Jun Wen – Southern California Edison
Keith White – California Public Utilities Commission
Cameron Yourkowsky - Renewable Northwest Project
Janice Zewe - Sacramento Municipal Utility District
Nan Zhang – Energy Exemplar
Carl Zichella – Natural Resources Defense Council